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MODULAR LANDSCAPES IN ARID CLIMATES

REDEFINING SUSTAINABILITY IN PUBLIC SPACE

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This paper proposes a set of sustainable Modular Design Principles (MDP) with direct applicability in different landscape contexts. Sustainable practices, such as the optimization between resources and costs, both in terms of construction and maintenance phases, are included in the structural reasoning.

MDPs here presented are included in a vaster group of landscape practices, used in several projects where important resources, such as water and soil, are scarce – especially in arid and semi-arid areas. A theoretical case study in the United Arab Emirates (UAE) is presented, in order to put the proposed MDPs up to the test. These principles do not close the theme of sustainable practices in landscape architecture, but rather deepen the discussion.

The definition of these sustainable design principles followed a modular approach, where different elements were isolated for deeper comprehension. Nevertheless, to understand those as a whole is quintessential in order to produce enduring integrated landscape solutions.

Conclusions demonstrate that the modular reasoning opens the possibility of continuous reinventions and adaptations to new techniques, new technologies and new operational wills in landscape.

Although proposed MDPs are contextualised within a limit situation - the desert climates – it is defended that this researches' operative conclusions can be applied as global models for integrated landscape design, as long as they are provided with specific adaptations regarding accurate relations between desired aesthetic attitudes, good sustainability practices and application site's specific characteristics.

Key words: sustainability, design principle, intensive/extensive areas, modular landscape, arid climate

1. Introduction

Over the last few decades, scientific community has gathered several important contributions concerning aesthetic principles and sustainability. Ian Thompson's 'Ecology Community and Delight', or Aronson's 'Aridscapes – Designing in harsh and fragile lands', among others, arise as inevitable references.

This paper seeks the proposal of sustainable Modular Design Principles (MDP) with easy and direct applicability in different landscape contexts. The main goal is their coherent and cohesive application, individually or duly combined, into landscape designs without compromising final result's aesthetical value, besides integrating sustainable concerns.

The different MDPs here presented were gathered from a vaster group of landscape practices, used in several projects, usually where important resources, such as water and soil, are scarce. They were obtained by successive design approximations and through the inclusion of technical and technological measures from professional fields close to landscape architecture. Indeed, this research's main objective is the definition of MDPs adapted to areas where resources are scarce – arid¹ and semi-arid areas².

1 Arid zones – deserts – are the result of a deficit of water due to having a hydrologic cycle in which the land loses more water than it gains (...) and are defined as having less than 250 mm rainfall per annum. There is a huge temperature difference between night and day, winter and summer, (...) that can result in extreme wind conditions" (Aronson, 2008, p. 29).

2 "Semi-arid zones (...) have from 250 to 500 mm annual rainfall with hot summers and cold winters. They have been described as being too dry to support a forest, but too moist to be a desert." (Aronson, 2008, p. 30).

Sustainability was carefully included in these principles structural definition, considering the concept in its most inclusive meaning, in which resources and costs are optimized, both in design, construction and maintenance phases.

The set of MDPs presented here do not conclude the fruitful theme of sustainable practices in landscape architecture. Rather, the aim of this paper is to deepen their discussion, presenting principles adapted to different areas with limited conditions, where resources are scarce and, therefore, precious – arid and semi-arid regions. These principles are tested in a theoretical case study in the United Arab Emirates (UAE), carefully described ahead.

2. Basic definitions and principles

This section addresses the fundamentals for the creation of MDP of sustainable nature in the particular context of arid and semi-arid regions.

2.1. The importance of sustainable solutions in arid and semi-arid regions

When designing in arid and semi-arid climatic conditions, the main limiting factors are scarcity of hydric resources, especially when acknowledging precipitation's extremely low values (from less than 250 mm to 500 mm of rainfall *per annum*), extreme temperatures, high rate of evapotranspiration and poor soils. In spite of these harsh conditions, social factors must also be considered, given that a green and luxurious landscape will always be the most appealing.

Despite global contemporary awareness with resource's optimization, extreme situations such as these arid and semi-arid zones, require this paper to clarify the operative concept of sustainability.

Sustainability is currently a widely explored theme, despite not always having equivalent significance. This paper considers United Nations Economic Commission for Europe's definition for sustainable development, which states that development should meet the needs of current generations without compromising the ability of future generations to meet their own needs. Other authors looked further into this definition, stating that sustainable landscape designs are those installed and managed in ways that, in the course of time, are able to improve human health, quality of life and commerce without excessive consumption of natural resources. (Martin, 2008, p. 2)

Seen from a professional point of view, sustainability means to pursue an accurate relation between wills and costs, desires and maintenance, hopes and efficient techniques and strategies. Sustainability means more efficiency and never less quality.

In arid and semi-arid regions, especially in areas where particular human and resources concentrations are felt, generating a huge burst of development, sustainability problems have become even greater. According to Kotzen, planning and design relate directly to the development of alternative landscape paradigms which require the appropriate use of plants and water harvesting, in particular in arid regions where water is extremely scarce and where sustainable solutions are quintessential.

Taking the particular case of the United Arab Emirates (UAE), Ouis (2002, p. 334) clearly states that "the Emirati state has transformed portions of the country's desert environment into green landscapes with enormous resources". The author refers to several environmental

problems present in the gulf states, concerning different implemented greening projects (agricultural and parks), such as: general use of high water demanding plants; soil erosion; extremely high rates of subsoil water loss (including non-renewable fossil water); and desalination of sea water to meet water demands (a process with enormous energy consumption and carbon dioxide release).

In order to fulfill sustainable principles, landscape systems' inputs and outputs must be minimized (Kotzen). Therefore, measures such as careful selection and placement of plants; strategies that decrease subsoil water loss and promote more efficient soil water retention; improved water management and irrigation through strategic use of local water and finding alternative water sources like 'grey water'³ are fundamental.

2.2. Modular Design Principle concept

Modular Design Principle (MDP) concept is born from the understanding of landscape as a complex reality with diverse operating levels with different lifetime periods. This holistic view of the landscape can be built through different sustainable design principles (SDP), with appropriate adjustments and recommendations for each site. Those principles will be depicted ahead.

It is important to stress that MDPs developed along this research are also a reflection of a strong conviction as landscape practitioners over the last decades, most of the times in areas where important resources, such as water and soil, are scarce.

Modular design is an approach that divides a landscape system into smaller cohesive parts - the SDPs. Each part can be created and used independently, as well as functionally sectioned into distinct scalable, reusable modules.

Modularity offers several benefits to landscape architecture's practice, such as the possibility of adding, extending or excluding solutions without compromising the efficiency of the initially defined range of MDPs. This happens due to the fact that these principles can be applied isolated or integrated into an overall design.

Depicted MDPs' nature must be of a flexible character; otherwise their applicability would not be useful in design terms. The design principles' range of application varies in scale and dimension. It is believed that these design principles can be effectively applied not only to different types of areas – parks, gardens, residential areas – but also to diverse socioeconomic contexts.

One of the most significant characteristics of the MDPs is their dynamism, firstly because it implies that the design can easily accommodate changes and recombination, and secondly due to the numerous operative scales. Independently of the project's scale, the promotion of an efficient and rational use of natural and economic resources is a constant in all the MDPs addressed in this study.

In addition, design principles are adaptable so that they can be incorporated simultaneously, either in intensive or extensive areas⁴. Furthermore new MDPs can easily be added to the original set of principles here defined, since they incorporate an open-source process.

³ Grey water is waste water generated from domestic activities, which can be recycled on site for uses such as landscape irrigation (Sustainable Sources).

⁴ Differences between intensive and extensive areas are carefully described ahead.

Ultimately, a certain ease of maintenance of the end result is required in order to fulfill the sustainable goals, once these principles are implemented.

Sharing the conviction that almost every existing landscapes are the result of complex artificial mechanisms, this paper's main objective is an optimization of natural processes, thus creating strongly adapted systems where human communities harmoniously share the territory with other living communities.

As previously mentioned, every design principle is born from a strong will of spatial formalization. Even with that conscience, the MDPs here presented prove its validity whatever the aesthetical concept.

3. *Modular Design principles*

3.1. Design criteria

Deserts and oasis are naturally occurring landscape features in arid regions and can hardly be imagined detached from each other (Bodeker, 1996).

In this research the duality between smaller areas of concentrated resources and energy and much wider ones, where these are scarce becomes clear as a parallel motto for adopted design criteria, thus defining intensive and extensive areas (Figure 1).



Figure 1: Castle Hillside, Silves, Portugal (PROAP), and Intensive and Extensive areas

Every design attitude within an intervention carries, in terms of energy and resources consumption; a clear notion of differentiation between intensive and extensive areas. While intensive areas, with greater carrying capacity, more irrigation and more planting areas, usually derive in leisure zones, extensive areas have almost no irrigation and operate mainly as landscape scenarios (Bodeker, 1996).

From a sustainable reasoning's point of view, it is defended that intensive areas should occupy reduced spaces in the overall area of intervention, especially as they imply higher demands of energy and resources. On the other hand, extensive areas may occupy greater portions of total surface, since they demand comparatively lower amount of energy and resources.

But design principles can go further: on extensive areas, efficiency is increased by mixing hard-soft covers. This strategy avoids unnecessary water consumption, while guarantying the

perception of a green continuum from the eye view, by providing right proportions and spacing between those different types of surfaces⁵.

Efficiency in irrigation systems is also increased through more intimate relations between drip systems and plant covers as well as a closer relation between water management and planting techniques. Plants must be carefully selected on a systematic approach based on adaptation to arid climates and specific water requirements, especially within the extensive areas.⁶

3.2. Modular Design Principles' Composition

Sustainable design is achievable through a balanced management of resources (water, matter, energy, and biodiversity) profoundly related to the site, its community and their activities.

For Dunnet & Clayden (2007) it is clear that adequate selection, use, manipulation and management of materials and resources, both organic and inorganic, is a central issue to achieve SDPs. Although, in terms of sustainable design, it is impossible to separate materials selection, resource manipulation and subsequent management from the creative design process, this study will be focusing mainly on resources' manipulation and management through design, and not so much on the importance of material selection. Regarding this selection, it is important to refer that a number of studies have been already conducted on this topic.

The main elements that shape MDPs in order to promote efficient uses of water and energy are: topography; microclimatic manipulation; conscious selection of plant material; and visual dynamics. Their description will be given later on this document.

3.3. Modular Design Principles

MDPs presented in this paper were born from different practice's intuitions, developed over the last few decades in integrated landscape solutions. They are the result of a design knowledge leveraged in many specialties close to landscape architecture.

MDPs are described in the following sub-chapters, and they are divided into two separate categories: efficient use of water and efficient use of energy.

3.3.1. Efficient use of water

“The design of an arid-zone garden can no longer afford to disregard any of the numerous strategies to add to the total available water.” (Aronson, 2008, pp. 43-45).

- MDP 01 – Run-off control

It is of strategic importance to protect and extend water sources in hot arid climates. The lack of water is the main limiting factor of all vegetation development in the desert, making intelligent and efficient strategies, such as rainwater collection and retention for irrigation purposes, a necessity. The main objective of these strategies is to avoid unnecessary losses of

⁵ This principle is depicted ahead, under the name 'MDP 02'.

⁶ This principle is depicted ahead, under the name 'MDP 03'.

rainwater by decrease water run-off in favor of water infiltration for irrigation purposes (Figure 2).

It is defended that rainwater run-off, from all impervious and asphalted surfaces, especially within extensive areas in the area of intervention, is guided and channelled in water collectors to the intensive areas to provide irrigation for the planting zones (Bodeker, 1996).

Rainwater can also be collected by modulating topography and ground covers in order to concentrate water in lower areas and facilitate irrigation, as it is described by the method of “oasification” (Azagra, Mongil, & Rojo, 2005), just as it occurs in nature. In real deserts, natural trees and vegetation can only exist in *wadis*, or dry riverbeds, which have good deep soil and very large rainwater catchment basins.

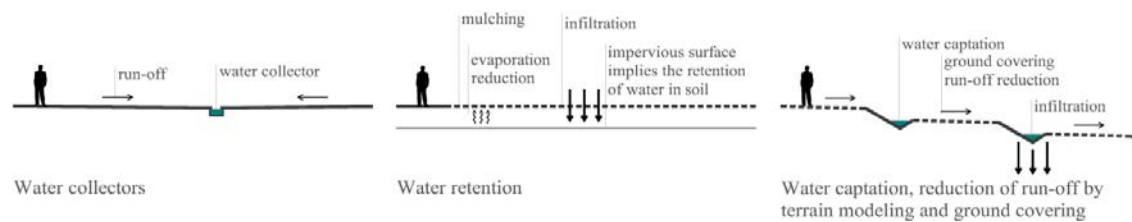


Figure 2: Run-off control [MDP01]

Combinations of strategies such as the application of an impervious layer at a certain depth of the soil profile (to decrease the water infiltration towards deeper soil horizons) and mulching (to decrease losses of water by evaporation on the ground surface) increase water retention in upper soil horizons, promoting water storage for direct intake of the existing root system.

In recent studies, Singer and Martin (2008) showed that organic mulches (such as recycled shredded landscape tree trimmings) have nearly the same effect on lowering under canopy temperatures as turf grass. These findings, combined with the possibility of recycling on site waste, make this option a very sustainable and thermally comfortable improving solution, without increasing consumptive water use (Singer and Martin *in* Martin. (2008, p. 9).

Besides controlling run-off water from local hard surfaces, other methods can help raise significant amounts of water for irrigation, such as air conditioner discharges and grey water collection. (Aronson, 2008)

- MDP02 – Efficient irrigation. Plantation strategies and techniques

Green landscapes in arid regions rely on water resources for irrigation, which, in most of the cases, are scarce. Therefore, efficient irrigation should guarantee enough water in order to avoid possible water stress in plants while reducing unnecessary water loss. Many researchers, among them Martin (2008), have demonstrated in technical terms what was already empirically acknowledged: the combination of efficient landscape irrigation systems, such as drip or trickle and the use of desert native or adapted landscape vegetation, reduces the landscape irrigation’s demands.



Reduction of green cover by terrain modeling and plantation on stripes, maintaining visual effect of green continuum

Figure 1: Efficient irrigation. Plantation strategies and techniques [MDP02]

MDP 02 (Figure 3) directly suggests a more efficient irrigation system by mixing hard-soft covers within garden's extensive areas. The idea is to substitute the total amount of green surfaces with more efficient ones, by maximizing spacing between hedges, whilst keeping the sensation of a green continuum at the eye level. A more efficient irrigation system can be intimately related and adapted to defined soft surfaces, therefore preventing irrigation in hard-surfaces and reducing total water consumptions.

In terms of irrigation's efficiency it is recommended the use of dripping systems instead of sprinklers, to reduce water evaporations and uneven water distribution due to wind. This system delivers water directly to where it is most needed, reducing waste. Furthermore, it is easy to install and to maintain and it has proven cost-effectiveness, despite initial installation expenses (Aronson, 2008). It also allows a correct control of water quantities and nutrients reaching plants. One should take into account the materials of water tubes covers and avoid solar exposure laying water pipes underground.

- MDP03 – Plant selection and location considering water requirements

Landscape design in arid and semi-arid climates should aim for sustainable and efficient water use by strategic plantation of plant communities of similar water requirements, which can help to inform how, where and when irrigation is needed, which is in fact considered a tenet of "xeriscaping"⁷.

In this sense, plant species should be located according with their water needs. All plants with low water requirements should be separated from species with medium to high water needs.

Extensive areas should be planted according to low water requirements; meanwhile plant selections in intensive areas can consider areas with both medium and higher requirements.

According to Martin (2008), Landscape Design Experiment Treatments in Phoenix (USA), rhizosphere soil temperatures (thirty centimeters below surface) are lower in turf grass areas irrigated with sprinkler systems than areas covered with inert surface mulch. Furthermore, outdoor surface temperatures in areas that integrate turf grass landscapes are cooler when compared with temperatures of areas surrounded by desert vegetation and inert mulch. These results emphasize the importance of latent heat transfer and turf grass in the creation of cooler microclimates. Based on these findings, future sustainable strategies should include the optimization of size, placement, and management of turf grass areas, as it happens in the intensive areas, rather than the total elimination of turf grass as a landscape element in favor of an environmentally warmer, composite, structured desert landscape archetype.

⁷ Xeriscape is a method of landscape design that minimizes the need for water use and protects the environment. There are seven principles associated to xeriscape landscapes: planning and design; soil improvement; appropriate plant selection; practical turf areas; efficient irrigation; use of mulches; appropriate maintenance. (Sustainable Sources).

- *MDP04 – Plant selection considering hydric stress*

Sustainable planting in arid and semi-arid regions should not always depend on irrigation. However, current landscape expectations and functions in public space require an initial input of water during establishment, and later, a minimum supply to avoid serious levels of water stress resulting in irreversible damage.

The induction of hydric stress to landscape plantings aims to reduce water use, avoiding injury symptoms related to excess of water, reducing soil erosion, and cutting down the costs of weed removing.

This technique consists of providing deliberately and successively water supply indexes below evapotranspiration inherent to each species, after an establishment and adaptation period, always aiming for acceptable landscape performances. Low and irregular irrigation (i.e. uneven frequency, duration and quantity) promotes root developing, which in turn, increases plant resiliency. (PROAP, 2011c)

Careful study, selection and use of drought tolerant plants are essential. Native species are already adapted to natural hydric stress. Many others are suitable for landscape planting in public spaces, and should be used instead of more demanding species, providing a minimum water supply whenever maximum allowed stress levels occur. These should be correctly grouped in hydro-zones⁸.

This procedure has been studied within the scientific community as a possible solution to reduce water consumption in vegetation with purely ornamental functions. Results of investigations at University of California revealed that irrigation substantially below referential evapotranspiration (20 to 60 % accordingly to the species and the climate zone) can be applied to established Mediterranean shrubs and plant covers with no apparent drought-related injury (Sachs, 1991).

3.3.2. Efficient use of energy

There was a special concern on microclimatic comfort provided by shade, geothermia, water, and wind and plant evapotranspiration. When combined together, these mechanisms promote real reductions in energy consumption needed for cooling.

By creating thermally comfortable outdoor spaces that can be used throughout the year, building's energy usages and associated carbon emissions of air conditioning systems are reduced. This becomes relevant when taking into consideration a holistic sustainability's definition, where, not also it is important to minimize inputs and outputs, but also to promote continued use of the space, to define balances between efficient uses of energy and to promote thermally comfortable outdoor living through microclimatic control.

⁸ Hydro-zones can be described as landscaped areas having plants with similar water needs that are served by one irrigation valve or set of valves with the same schedule (Sachs, 1991)

- *MDP05 – Microclimate regulation with shade*

In arid and semi-arid regions sunlight is harsh, even in shaded areas. Additional cares have to be made especially with its reflection. Therefore, the creation of transitional light zones is an important design consideration (Aronson, 2008).

Shade has direct and indirect influence in microclimatic comfort. Direct sun, also called radiation, can increase perceived temperature by as much as 20°C. Indirect radiation is also important - surfaces exposed to direct sunlight absorb heat and increase temperature by re-radiating heat. In addition, by shading the ground, less solar energy reaches it, so less is absorbed by the surface and radiated back to the air as heat (Panagopoulos, 2008).

In order to regulate thermal comfort, the strategy of shading areas in outdoor spaces in hot arid climates is based on air temperature decrease by limiting, on the one hand, direct solar radiation and, on the other hand, indirect radiation from ground surfaces exposed directly to sunlight. Besides, shading enhances air circulation and thermal exchange.

A comprehensive shade solution in outdoor spaces should most likely incorporate a combination of both natural (individual trees, alleys, buffers, climbers growing on pergolas) and built shade elements (such as system of pergolas, fences, solid cubes) (Figure 3).

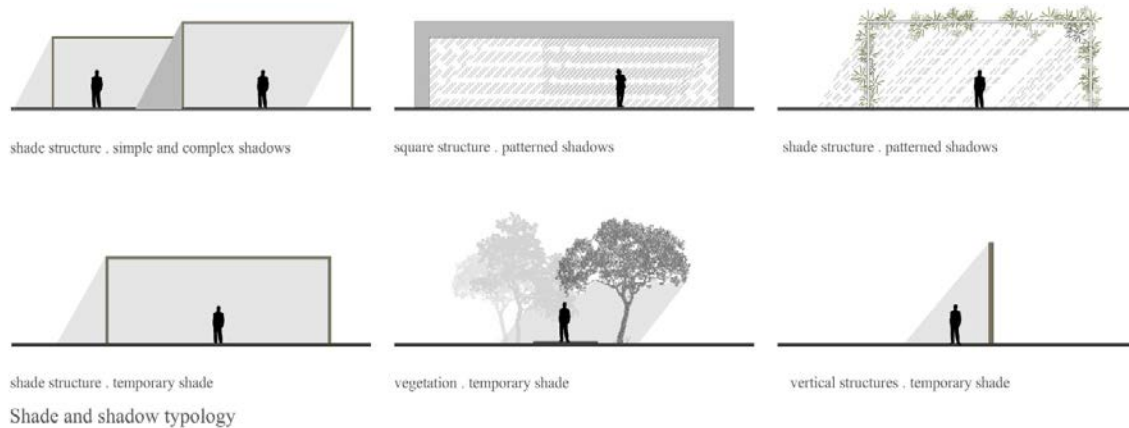


Figure 2: Microclimate regulation with shade [MDP05]

The diversity of shade's intensity according to different mesh patterns and to different densities of vegetation canopies provokes different shading ranges and, therefore, different thermal comfort within the different areas.

Havig in mind the importance of water management in arid regions, a synergetic approach of combined strategies in terms of thermal comfort as well as water-use efficiency should be considered. (Shashua-Bar, Pearlmutter, & Erell, 2009)

- *MDP06 – Microclimate regulation with geothermics*

The following principle relies on the principle of geothermy by taking profit from thermal inertia existing within the ground surface to obtain thermal comfort inside sunken or underground spaces, as it occurs in nature, in grottos or caves (Figure 4).

Inner microclimate is cooler in summer and warmer in winter in relation to outdoor temperatures, which guarantees thermal comfort throughout the year. For one given intervention area, inner temperatures are around the annual temperature average of the air.

The gradient of atmospheric temperature between maximum and minimum is reduced underground, due to thermal inertia of the ground mass. The annual variations of the outside temperature fall more abruptly than the ones inside the sunken structures. Moreover, the thermal inertia of the ground walls and ceiling underground provokes several months of delay of the maximum and the minimum inner temperatures, when related to outdoor temperatures.

Finally, the relative humidity of the inner air is higher because of the humidity stored underground, which circulates as water steam through the ground walls and the ceiling.

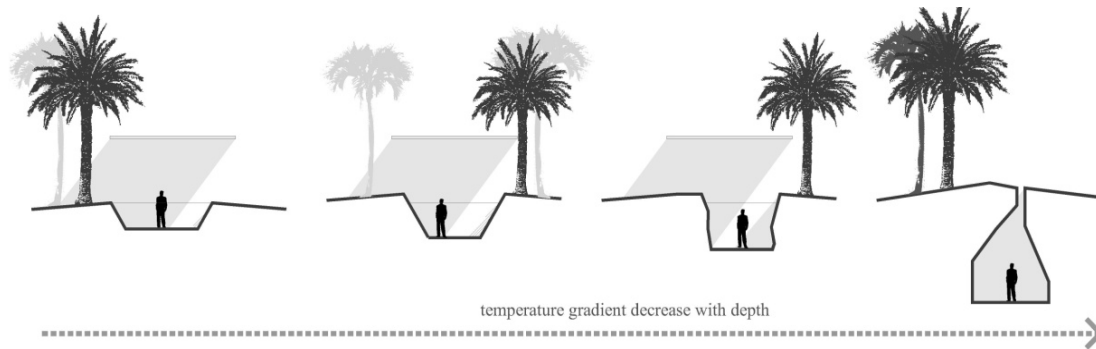


Figure 3: Microclimate regulation with geothermics [MDP06]

- *MDP07 –Microclimate regulation with water*

Through evapotranspiration, plants have strong results on microclimate control with regard to outdoor spaces, therefore resulting in an effective way to significantly reduce energy for cooling purposes (Panagopoulos, 2008). On the one hand, vegetation provides solar protection by shading and, on the other hand, vegetation's evapotranspiration can significantly reduce outdoor temperatures (Figure 5).

Micronebulization is a strategy that consists on providing air cooling through water misting mechanisms that guarantee climate comfort in specific areas within the garden. Micronebulization systems create fog with extremely fine water droplets; the smaller the droplets, the faster they get energy and evaporate, generating immediate air temperature decrease (Figure 5). The effectiveness of the refreshing effect through evaporative cooling is influenced by multiple factors, such as the amount of the involved mass of air, the movement and regeneration of air and the existence of shade in the site. Water misting systems are more efficient in confined spaces, protected by shade structures where air ventilation is guaranteed (PROAP, 2011a).

Water features serve as natural air conditioners in outdoor spaces. Potential of open static and dynamic water features (for lowering air temperatures and reducing the heat island effect generated by most hardscape surfaces), is suggested for natural cooling with water in outdoor spaces. Appropriate inclusion of open water systems within the landscape can improve microclimatic conditions and thus thermal comfort during hot periods of the year.

The evaporative cooling strategy is based on the air and water heat transmission. High air temperatures potentiate evaporation processes, as atomic and molecular particles in liquid state gain sufficient energy to enter the gaseous state. The water draws heat as it evaporates, decreasing the air temperature along the process.

Water features can also be used for direct refreshment such as accessible water basins, water channels or water fountains, where human body can contact directly with water without actually using much water.

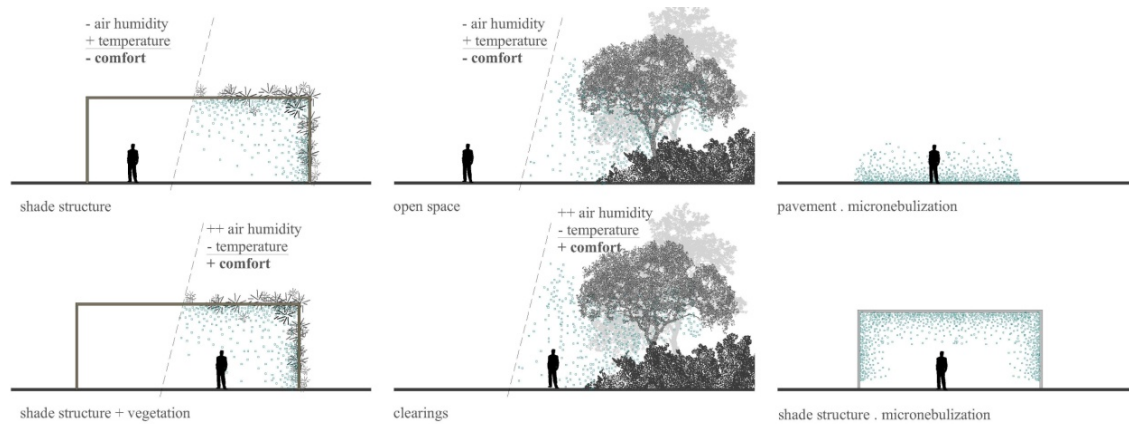


Figure 4- Microclimate regulation with water [MDP07]

- *MDP08 – Microclimate regulation with breezes/wind current*

The succession of open and enclosed areas influences wind speed and direction within the landscape, generating local wind breezes which can provide microclimatic comfort. The presence of outdoor shading structures generates an important air renovation as well. Shade will produce spatial gradients in soil's temperature and paved surfaces along the day and air movement will occur at micro scale range.

The bioclimatic comfort provided by air currents is well exemplified in Middle Eastern vernacular architecture, matured over time and shaped by hot arid climate, such as the *Malgaf* or wind tower. This exemplar structure is used to trap cooler air at a high level and delivers it to users resting at a lower level. Very often there is a water reservoir inside the lower level, allowing for humidity regulation as well. This method offers an energy-free air-conditioning natural system and comfortable indoor conditions with almost no costs to both the environment and users.

- *MDP09 – Lighting on demand*

Lighting on Demand (LoD) is a lighting concept based on the creation of a light wave that follows users according to their movement along the public space. It can be used in different sorts of spaces, according to the distinct appropriations they foster (Figure 6).

LoD promotes the reduction in terms of total annual energy consumptions and in annual carbon emissions, especially when compared to traditional systems. LoD has been studied as a premise for an integrated public space design, but it is believed that it can also be applicable in private spaces, provided that specific adaptations are made.

This system's main innovation is focused on the promotion of stronger links between user's movement and lighting waves (PROAP, 2011b).

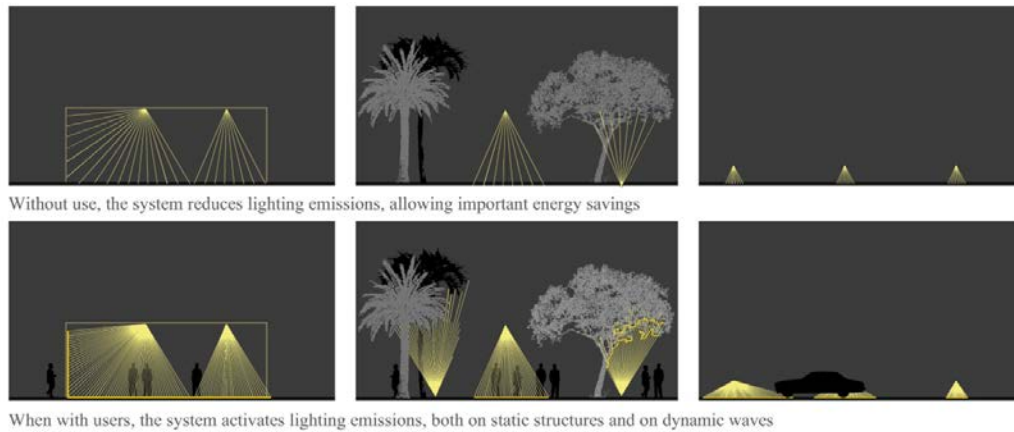


Figure 5- Lighting on demand [MDP09]

3.3.3. Modular Design Principles Synthesis

In this sub-chapter a comparative synthesis of empirical base is presented. This table's objective is to be part of more efficient query tools, allowing not only landscape architects, but other professional fields with concerns about landscape solutions as well, to have more accurate conscience on their design's outcomes.

Table 1 Modular Design Principles Synthesis

Modular Design Principles		Intensive Areas	Extensive Areas	Save:					Promote:
				matter	air	water	energy	biodiversity	uses
Water	MDP01 Run-off control	●	●	●	●	●	○	○	○
	MDP02 Efficient irrigation. Plantation strategies and techniques	●	●	●	○	●	●	○	○
	MDP03 Plant location considering water requirements	●	●	●	●	●	○	●	●
	MDP04 Plant selection considering hydric stress	●	●	●	●	●	○	●	●
Energy	MDP05 Microclimate regulation with shade	○	●	○	○	○	●	○	●
	MDP06 Microclimate regulation with geothermics	○	●	○	○	○	●	○	●
	MDP07 Microclimate regulation with water	○	●	○	○	○	●	○	●
	MDP08 Microclimate regulation with breezes / wind current	○	●	○	○	○	●	○	●
	MDP09 Lighting on demand	●	●	○	○	○	●	○	●

4. Theoretical case study – Private landscape in the United Arab Emirates (UAE)

MDPs were tested in a design project for a garden's palace in the UAE. This landscape presented both private and public areas and its aesthetic was raised from the will to exacerbate the senses (Figure 7).

The aim of this project was to achieve constructive solutions with high sustainability performances, both in terms of efficient uses of water and energy, but also in terms of landscape maintenance costs, once it reaches higher levels of maturity.

SDPs operated as structural elements working together in order to achieve pronounced coherence in solutions that offer great visual, sensorial and ecological diversity. The landscape values became not only formal codes imprinted on the territory, but sustainable rhythms, actions and reactions that enhance ecological and landscape valuable functioning over the time.

Different senses – sight, sound, scent and touch – were explored in different design solutions: the creation of visual corridors of illusionary deepness, a succession of open and closed spaces that potentiate comfort, well-being and relaxation; wooden pergolas merged in complex of structures, providing mixed indoor and outdoor atmospheres, and working in light manipulation; and underground gardens, hidden from the surface, among others.

In this particular case study MDPs have proven its applicability under strong aesthetical wills, meeting initial client's demands and technical and technological measures. In general terms, one believes that its application becomes possible in very different landscape contexts, as long as aesthetic principles are properly interlocked with sustainability practices and site's features.



Figure 6- Private landscape in the UAE sections (PROAP)

5. Assessment tools

“Sustainability is not (...) merely an abstract virtue nor simply a brake on decline. It will deliver important benefits” (Young, 1996, p. 8). These benefits for the future generations are measurable through environmental certification tools.

In order to validate MDPs outlined above it is possible to quantify and evaluate their sustainable effectiveness through renowned Environmental Certification, such as the World Sustainability Society⁹ (WSS) or the ESTIDAMA Program¹⁰.

These methods provide a set of measurable guidelines which allow rating the sustainability performance of different systems and quantifying the impacts that human activities generate in the environment, representing a reliable sustainability benchmark tool (ESTIDAMA).

This sort of assessment tools reward measures adopted during the design development/process that meet the intention to preserve natural resources and create more comfortable and healthier systems (ESTIDAMA). Procedures considering reducing water and energy consumptions, promoting biodiversity and improving natural systems' quality contribute positively to sustainable certification achievement.

Therefore, MDPs that represent efficient strategies to promote rainwater collection and retention for irrigation purposes (MDP01) will reduce the impacts regarding water resources, along with strategies that avoid unnecessary losses, as MDP02, 03 and 04. Design principles that contribute to reduce soil erosion or to promote biodiversity and ecological enhancement, such as the use of native species (MDP04), also add beneficial marks to the assessment.

It is important to stress that, along with the concern to preserve natural resources, it is crucial to create comfortable systems, pleasant for users. Public spaces should have different energy and resources inputs, depending on their type of use - intensive and extensive areas.

Microclimate regulation using shade, geothermic and water (MDP05, 06 and 07) will enhance thermal comfort, besides helping economizing energy needed for cooling purposes. Though using water for cooling may not seem an effective sustainable practice, it is believed that it will improve significantly outdoor comfort. Allowing "eco-compensation", as it happens in evaluation methods like WSS, makes it possible to quantify results into a standard unit, enabling the usage of mitigation procedures in extensive areas, which act mainly as landscapes scenarios.

From these programs interpretation, the ideal situation is to establish a balance between intensive and extensive areas, incorporating the maximum number of sustainable principals in the design process, in order to obtain the best results when assessing sustainability performances.

According to Dunnet & Clayden (2007) this performance and its assessment will become an essential element of design decision making, due to the growing interest in sustainable design certification schemes which for some developers are now compulsory.

6. Conclusions and considerations

A sustainable designed landscape has a tendency to be a closed homeostatic system, in such a way that inputs are reduced and there is a maximization of internal cycling of both materials and resources. On the other hand, unsustainable systems lean towards high resource inputs,

⁹ WSS is a non-profit foundation which the main goal is to create an universal measure of sustainability that allows to quantify the impacts of human activities on the natural resources (WSS).

¹⁰ Program managed by Abu Dhabi Urban Planning Council (UPC) to promote sustainability and enhance liveability in the emirate under the ambit of Abu Dhabi Vision 2030 (ESTIDAMA).

minimizing internal cycling and releasing substantial waste and energy (Dunnet & Clayden, 2007).

When attempting to define MDPs in different sustainable vectors, it is quintessential to understand the importance of resources and costs optimization, both in terms of construction procedures and maintenance phases.

As previously mentioned, sustainability is comprehended also as the definition of accurate relations between aesthetic wills and building and maintenance costs. Above all, sustainability means more efficiency and never less quality.

The definition of sustainable MDPs followed a modular approach, where different elements were isolated for deeper comprehension. However, it is fundamental to stress that a holistic understanding of these principles is needed for higher integrated landscape solutions achievement.

This modular approach's greatest advantage is the possibility of continuous reinvention and adaptation to new techniques, new technologies and new operational wills in landscape. Far from binding to certain operative methods used in landscape architecture's practices, this theoretical research seeks to present, in a clear but uncompromising way, integrated landscape design solutions sustained by most suitable sustainable practices currently in practice.

The authors firmly believe that the practices within this document can operate as global models, as long as they are provided with specific adaptations regarding accurate relations between desired aesthetic attitudes, good sustainability practices and application site's specific characteristics.

However, for this reasoning to be widely accepted and correctly used in landscape, it is also fundamental to believe in different, perhaps more sustainable, dry landscape's paradigms.

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8. Main author's biographies

JOÃO NUNES

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Founder and CEO of the Landscape Architecture Studio PROAP, which gathers a vast group of professionals in a cross-disciplinary team, with distinguished levels of expertise in landscape, in its most inclusive conception.

As International Director is responsible for the strategic, executive and tactical leadership of the three international offices: Lisbon (Portugal), Luanda (Angola) and Treviso (Italy). Develops PROAP's conceptual and creative design and defines the strategic orientation of the research processes.

Has been lecturing at the Instituto Superior de Agronomia in Lisbon (Agronomics Institute, Technical University of Lisbon) since 1991. Currently also lectures at the Istituto Universitario de Architettura de Venezia, Politecnico de Milano, Politécnico di Torino, Roma La Sapienza, Roma Ludovico Quaroni, Facoltà di Architettura di Alghero.

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